

RESONANCE INVERSION FOR ELASTIC MODULI OF ANISOTROPIC ROCKS

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RESEARCH OBJECTIVES

Heterogeneities in rock in the form of systematically oriented mineral grains, bedding planes and aligned microcracks often result in anisotropic bulk stress-strain behavior that can be described by anisotropic elastic moduli. Although these elastic constants can be determined either statically from load-displacement tests or dynamically from the velocities of elastic waves, cumbersome testing procedures, including the preparation of multiple, oriented samples, makes the determination of the anisotropic elastic moduli difficult. However, acoustic resonance spectroscopy has been successfully applied to small single crystals and minerals. This research applies a similar technique to determine the elastic moduli of rocks with anisotropic properties resulting from micro-scale heterogeneities.

APPROACH

Acoustic resonance spectroscopy is a technique for determining the dynamic elastic constants of a specimen using steady-state vibration of a specimen of known geometry. The technique consists of resonating the specimen over a broad range of frequencies, measuring the resonance frequencies and computing the elastic constants by nonlinear inversion of the measured resonance frequencies. Mode shapes of the anisotropic specimens are also measured using a laser Doppler vibrometer and compared with the prediction by the numerical model with the inverted elastic constants.

ACCOMPLISHMENTS

A comparison of experimental and computed frequency responses for the inverted moduli of a granite specimen (transversely isotropic based on observations by optical microscope and ultrasonic transmission tests) is shown in Figure 1. Although there are discrepancies between spectral amplitudes, the resonance frequencies and the general shapes of the responses showed good agreement. A comparison between the elastic moduli determined by static loading tests, resonance inversion and ultrasonic transmission tests showed reasonable agreement between the ultrasonic and resonance results, but the moduli determined from ultrasonic measurements were consistently higher than the resonance inversion. This result may be due to the slight frequency-dependence of the wave velocity in microscopically heterogeneous rock and non-elastic (frictional) deformation of the rock specimen during the static loading tests.

SIGNIFICANCE

Since acoustic resonance spectroscopy uses wave frequencies (frequency range) that are lower than those of the ultrasonic transmission tests (100

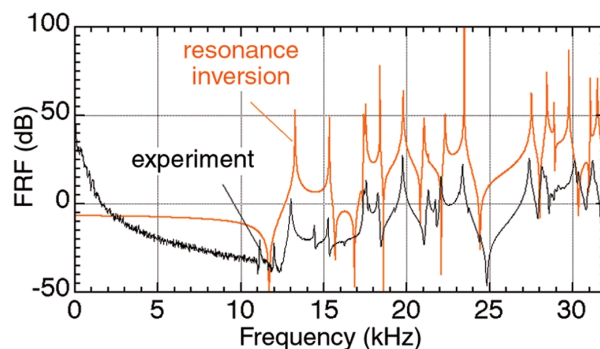


Figure 1. Comparison of experimentally measured and computed frequency responses of an anisotropic granite cube specimen. The computed response is for the five elastic moduli inverted from measured resonance frequencies.

kHz ~ several MHz), frequency-dependent dynamic properties of rock can be examined from comparison with the obtained elastic moduli. In contrast with other techniques, the acoustic resonance technique requires only a single or a few measurements for determining anisotropic elastic constants of the specimen. Although the current technique requires modifications for measurements under realistic confining stresses, the results indicate that it can be a powerful tool for characterizing the anisotropic and frequency-dependent elastic properties of rocks.

RELATED PUBLICATIONS

Nakagawa, S., Acoustic resonance characteristics of rock and concrete containing fractures, Ph.D. thesis, UC Berkeley, 1998.

ACKNOWLEDGEMENTS

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